Dual voltage vehicle power supply

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Abstract of **GB2342515**

A power supply circuit for an on-board electrical system of a motor vehicle, having two voltage supply branches Z1, Z2 at different voltage levels. The first voltage branch Z1, typically 12V, is used to supply low consumption loads and is fed power from the second voltage branch Z2 via an electrical DC/DC converter W1 or from a battery B1. The second voltage branch Z2, typically 36V, is used to supply high consumption loads such as the starter motor S and heaters and is fed power from a generator G or from battery B2. A second, bi-directional, DC/DC converter W3 is provided to monitor the state of charge of the two batteries B1, B2 to set the power flows between its inputs/outputs. The second converter W3 is used when, in addition to the normal operation described above, a) the voltage branch Z1 is powered from battery B2, b) the voltage branch Z2 is powered from both batteries B1 and B2 or c) when the battery B1 is charged from the voltage branch Z2.

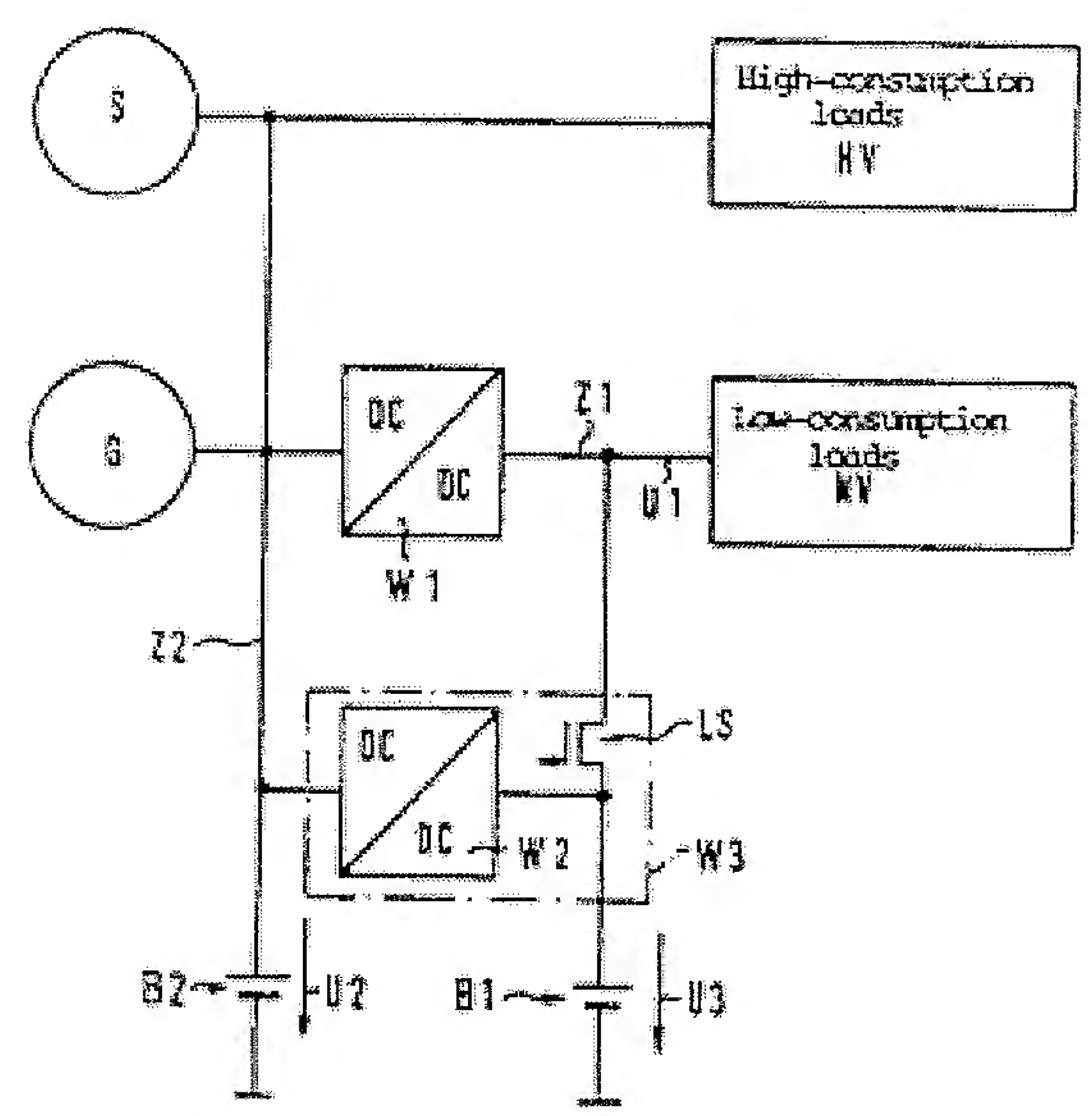

FIG. 1

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US 5334926 A

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(54) Abstract Title
Dual voltage vehicle power supply

(57) A power supply circuit for an on-board electrical system of a motor vehicle, having two voltage supply branches Z1, Z2 at different voltage levels. The first voltage branch Z1, typically 12V, is used to supply low consumption loads and is fed power from the second voltage branch Z2 via an electrical DC/DC converter W1 or from a battery B1. The second voltage branch Z2, typically 36V, is used to supply high consumption loads such as the starter motor S and heaters and is fed power from a generator G or from battery B2. A second, bi-directional, DC/DC converter W3 is provided to monitor the state of charge of the two batteries B1, B2 to set the power flows between its inputs/outputs. The second converter W3 is used when, in addition to the normal operation described above, a) the voltage branch Z1 is powered from battery B2, b) the voltage branch Z2 is powered from both batteries B1 and B2 or c) when the battery B1 is charged from the voltage branch Z2.

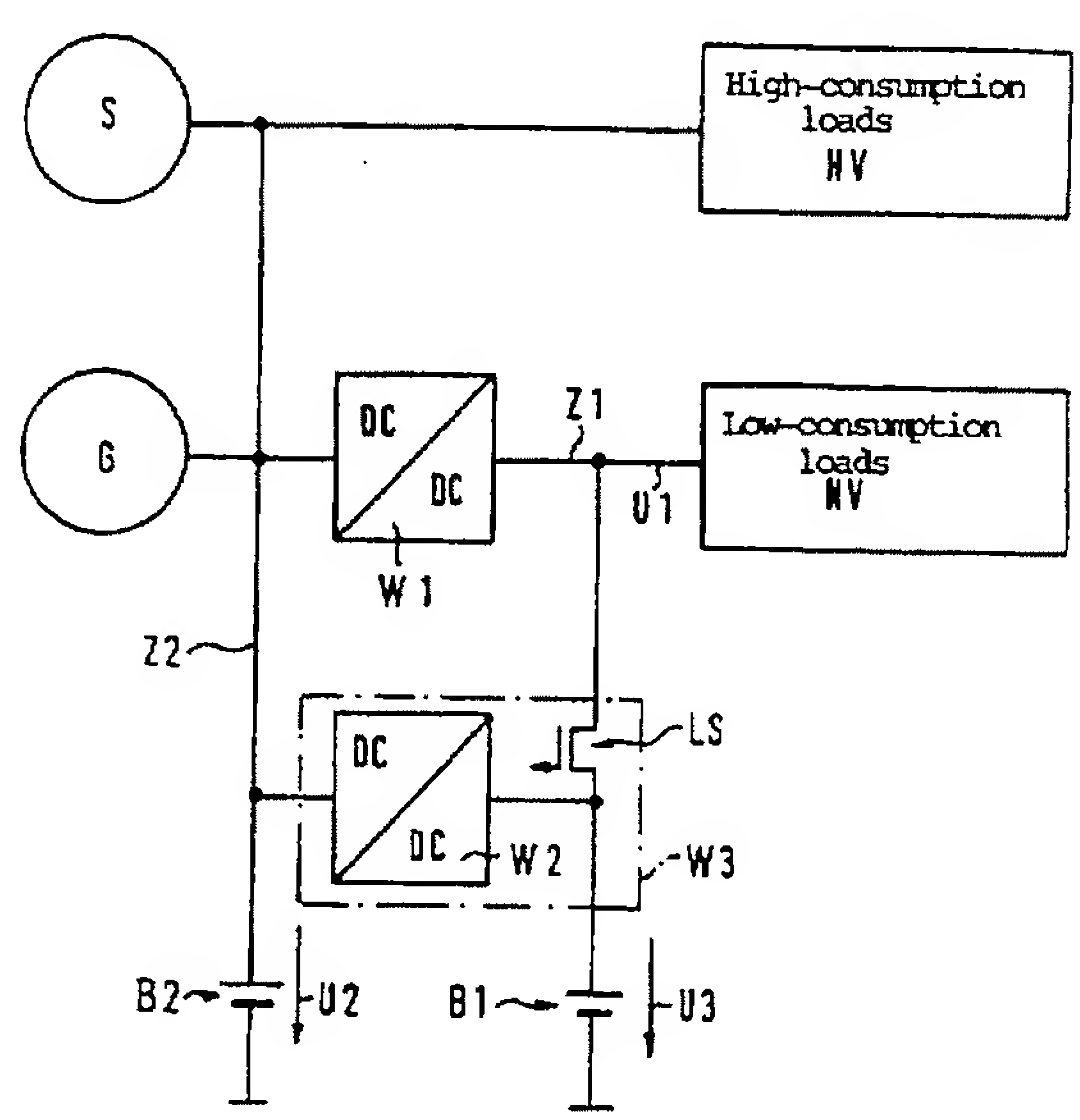

FIG. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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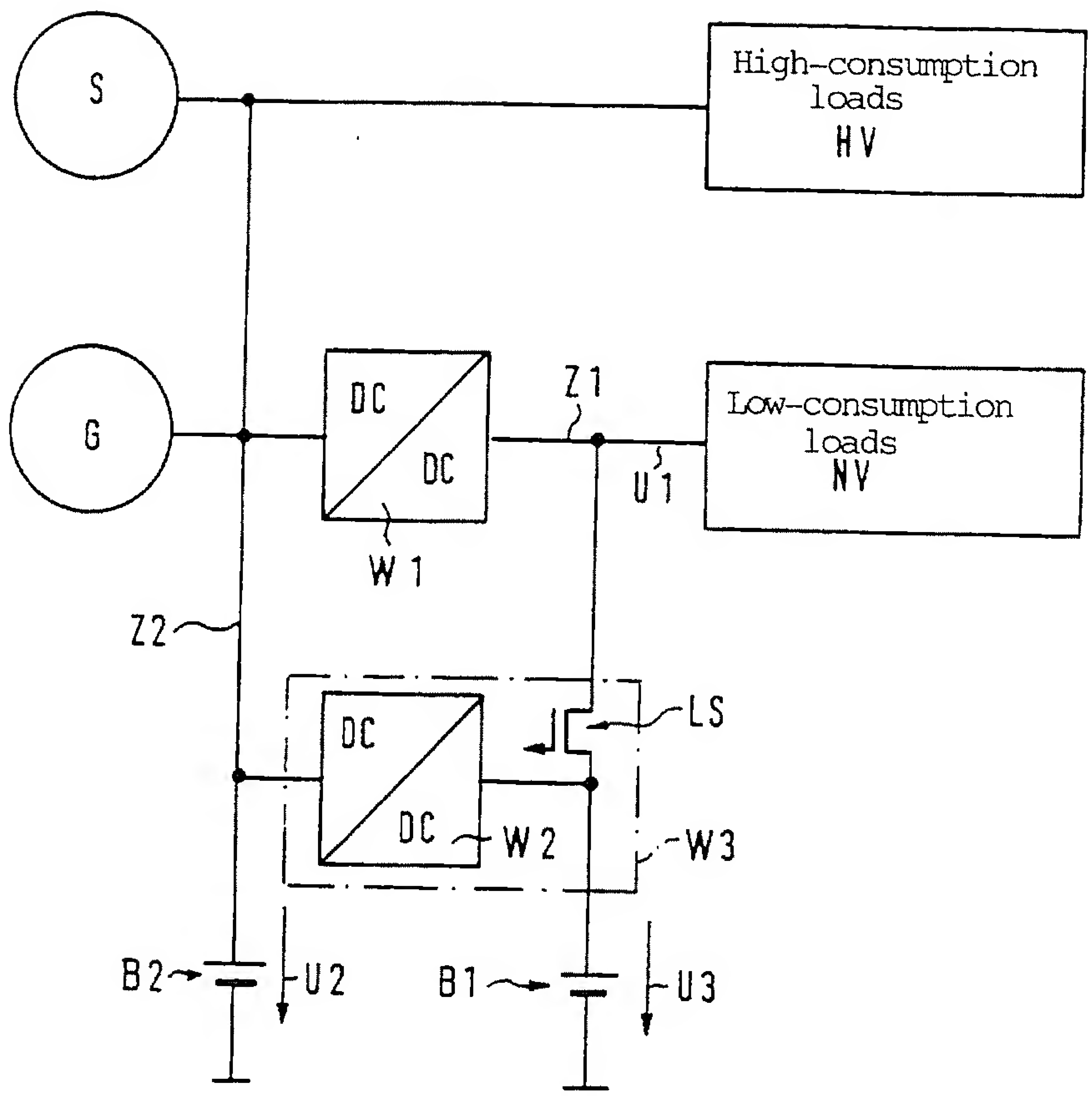

S
High-consumption loads
HV
G
DC
DC
Z1
Low-consumption loads
NV
U1
W1
Z2
DC
DC
LS
W2
W3
B2
U2
B1
U3

FIG. 1

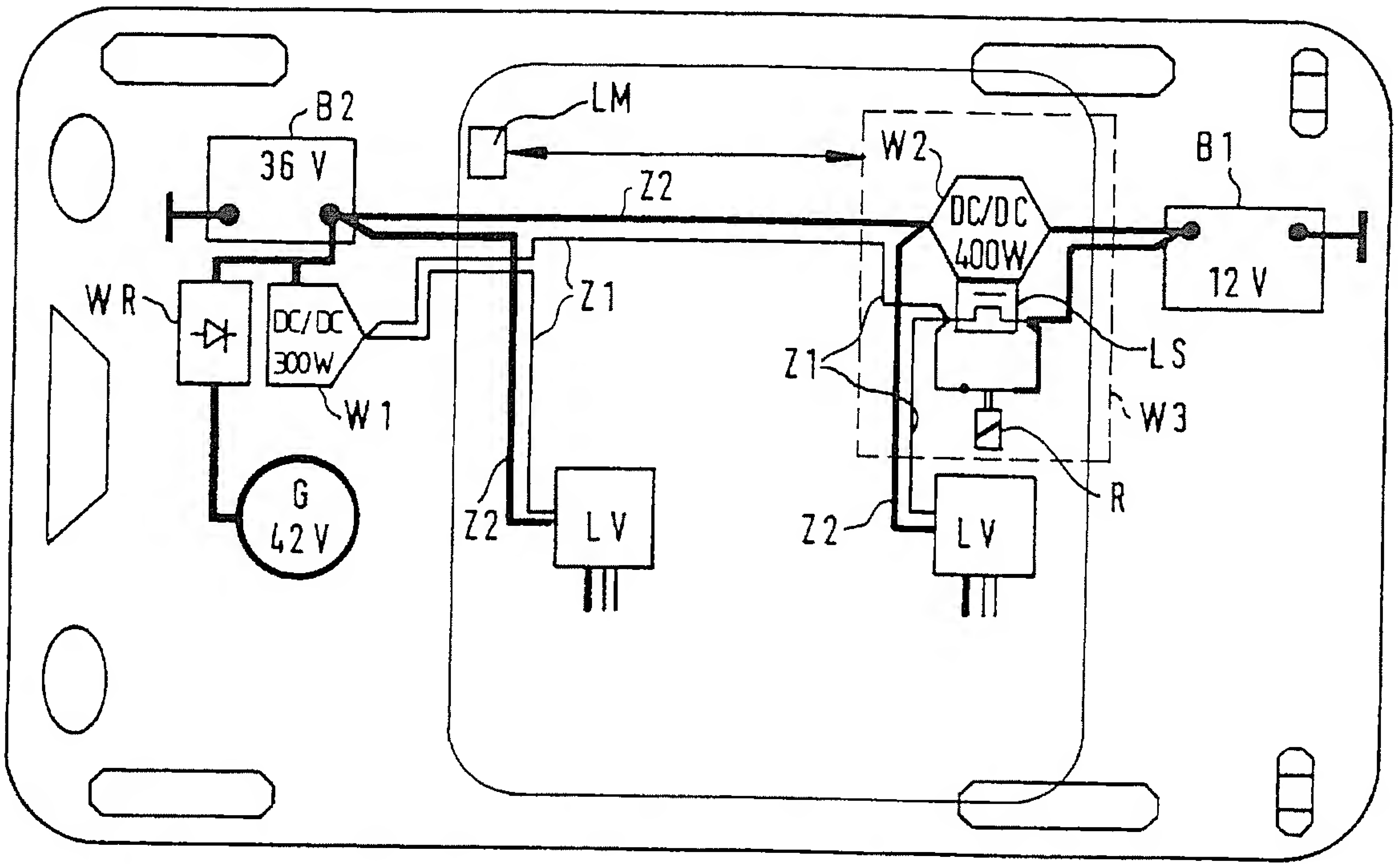
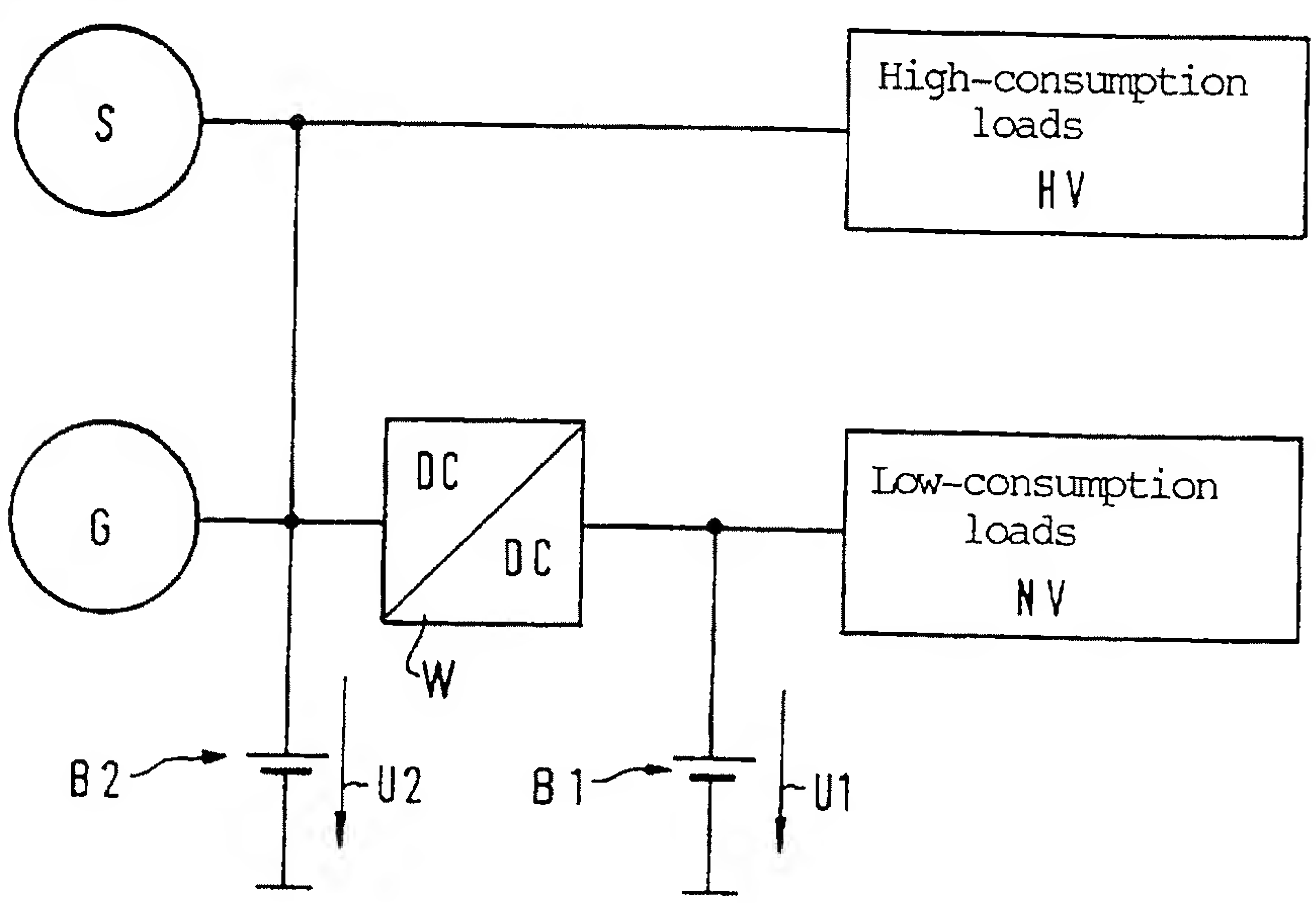

B2
36 V
LM
Z2
W2
DC/DC
400W
B1
12 V
WR
DC/DC
300W
Z1
W1
Z1
LS
W3
R
G
42 V
Z2
LV
Z2
LV

FIG.2

FIG.3


S
High-consumption
loads
HV
G
DC
DC
W
Low-consumption
loads
NV
B2
U2
B1
U1

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Power supply circuit for an electrical system of a motor vehicle

The invention relates to a power supply circuit for an on-board electrical system of a motor vehicle, having two voltage supply branches.

The development of new components in automobile construction, such as electromagnetic valve control (EMVC), the electrically heatable catalytic converter, etc., and the trend to drive by electrical means components previously driven via belts, have caused the total electrical power of the loads to be supplied to grow sharply. This power requirement can no longer be covered sensibly using the current 12 V on-board electrical systems with a 14 V generator voltage. It is known to superimpose higher voltage levels on the 12 V on-board system, these higher voltage levels feeding the high-consumption loads, for example EMVC, heaters, fans, adjusting motors. Loads with a lower power demand still remain at the 12 V level.

It is becoming increasingly apparent that an on-board system with a 42 V voltage supply for high-consumption loads, and a 12 V or 14 V voltage supply for low-voltage loads, such as the lighting or electronic controllers, is the objective. The voltage level of the high-consumption loads has therefore been raised to three times the current 14 V level (generator voltage).

On-board electrical arrangements having two batteries which can be coupled in terms of energy are disclosed by DE 40 28 242 A1 and DE 38 41 769 C1, the batteries being at an approximately identical voltage level of 12-14 V. Furthermore, DE 196 00 074 A1 discloses an on-board vehicle electrical system having two voltage levels, the higher voltage level being implemented by a parallel connection of a number of chopper stages.

In a typical configuration, which is known per se and illustrated in Fig. 3, a generator G buffered with an energy storage means B2 feeds a starter S and a 42 V electrical system for the high-consumption loads HV. The 14 V electrical system of the low-consumption loads NV is supplied via a power electronic unit whose input is connected to the generator G, for example by a DC/DC converter W, for example a unidirectional step-down controller (Buck converter) or a bidirectional step-down/step-up controller (Buck/boost converter). The 14 V electrical system is also buffered by an energy storage means, battery B1, in order to dissipate load peaks and against overvoltages.

With the elevation of the voltage level of the high-consumption loads to 42 V, a number of advantages result. The rectifier losses in the generator are reduced to one third. The reduction in the currents with the same output enables a reduction in cable cross sections, the easier use of semiconductor switches, the replacement of screw connectors by plug-in connectors, etc. The relative voltage drop and the earth offset are also reduced. Further advantages and advantageous operating modes of the known on-board system architecture will be sketched below.

In the on-board electrical system configuration described, the applicant considers it to be disadvantageous that the voltage limits to be specified for the 14 V branch of the low-voltage loads NV have to include the entire voltage range which results from the necessary charging voltage, on the one hand, and, on the other hand, the discharge voltage during buffering operations in order to cover peak outputs or to supply loads when the engine is at a standstill. Thus, when conventional lead-acid batteries, for example, are used for the loads, a tolerance band of 11-16 V is necessary. If other battery types are used, for example NiMH nickel-metal hydride batteries, a still wider tolerance band may be necessary because of different relationships between the final charging voltage and the final discharge voltage.

The voltage range which occurs in the electrical system places particular requirements on the design of the loads, increases the costs and may result in negative reactions, such as shortening the service life of incandescent lamps.

The present invention is, whilst maintaining the advantages of the on-board electrical system architecture outlined, to improve this with the effect that a narrower tolerance band for the loads is made possible.

According to the present invention there is provided a power supply circuit for an on-board electrical system of a motor vehicle, having two voltage supply branches at different voltage levels, the first voltage supply branch being fed from the second voltage supply branch via an electrical DC converter, and the second voltage supply branch being fed from a generator, at least one voltage supply branch being buffered by an associated energy storage means,

wherein there is a multiple converter having three voltage levels, whose one input/output is connected to the second voltage supply branch, whose other input/output is connected to the first voltage supply branch and whose third input/output is connected to an energy storage means assigned to the first voltage

supply branch, the multiple converter permitting a variable division of the power flows between various inputs/outputs as required

According to the invention, the low-voltage electrical system (first voltage supply branch) is no longer connected directly to the energy storage means B1 assigned to it, but via a multiple converter W3 (multi-level controller).

Decoupling the supply of the low-voltage electrical system from the battery terminal voltage makes it possible to regulate the output voltage of the first converter W1, which feeds the electrical system of the low-voltage loads NV, to a fixed value U_E, which corresponds to the discharge voltage of the battery. By this means, a narrow tolerance band (e.g. 11.8 V ... 12.8 V) can be predefined for the supply voltage, which makes the design easier and, for example in the case of incandescent lamps, prolongs the service life.

In a further development, the decoupling makes optimum and rapid battery charging possible, using a charging voltage U_L which is, for example, matched to the temperature of the battery, without undesired reactions on the low-voltage loads NV in the first voltage supply branch, which is fed with the lower, more closely toleranced discharge voltage U_E.

Depending on the voltage relationships in the on-board electrical system, the multiple converter W3 can be switched into further advantageous operating modes.

Details and advantageous developments of the power supply circuit according to the invention emerge from further subclaims in conjunction with the following description.

An embodiment of the invention is illustrated in the drawing and will be explained below. In the drawing:

Fig. 1 shows a circuit diagram of the power supply circuit according to the invention,

Fig. 2 shows an arrangement of the power supply circuit according to the invention in the vehicle, and

Fig. 3 shows a power supply circuit according to the prior art.

Fig. 1 shows the power supply circuit according to the invention, which has been developed further from the above-described arrangement according to the prior art in Fig. 3. The generator G, which is buffered by the energy storage means B2, feeds the starter S and the 42 V electrical system for the high-consumption loads

HV, which are part of the second voltage supply branch Z2. The electrical system of the low-consumption loads NV in the first voltage supply branch Z1 is supplied with a constant, closely toleranced supply voltage U1 via a DC/DC converter W1, especially a step-down controller (Buck converter), whose input is connected to the second voltage supply branch Z2. The converter W1 is preferably designed in such a way that it is able to cover the basic load in the first voltage supply branch Z1.

The energy storage means B1 assigned to the first voltage supply branch Z1 is coupled to both voltage supply branches Z1, Z2 via the multiple converter W3. The multiple converter W3, having three voltage levels, makes it possible to control the output between its three inputs/outputs, each input/output being adjusted to one of the three voltage levels U1, U2, U3.

For the application envisaged, the multiple converter W3 can be constructed in simplified form from a conventional second DC converter (DC/DC converter) W2 and a power circuit breaker (MOSFET transistor) LS, as is illustrated in Fig. 1 within the dash-dotted box. The power circuit breaker LS can be used to interrupt the power flow between the first energy storage means B1 and the second DC converter W2, on the one hand, and the first voltage supply branch Z1, on the other hand.

It is advantageous if the comparatively inexpensive first converter W1 is designed in such a way that it is able to cover the basic load in the first voltage supply branch. Then, during normal operation, the multiple converter W3 can be set such that it feeds no power flow into the first voltage supply branch Z1.

The multiple converter W3 or the converter W2 and the power circuit breaker LS can be put into the following operating modes as a function of the voltage relationships in the entire on-board electrical system:

During charging operation, the multiple converter W3 is regulated such that the first energy storage means B1 is fed from the second voltage supply branch Z2, the third input/output, which is connected to the energy storage means B1, being regulated to a charging voltage U_L of the energy storage means B1. In the simplified design, during charging operation, the power circuit breaker LS is opened and the output voltage of the second converter W2 is adjusted such that, in order to charge the energy storage means B1, the converter is regulated to the final charging voltage U_L, which corresponds to the necessary voltage to achieve a 100% full charge of the energy storage means B1. Because the energy storage means B1 is decoupled from

the first voltage supply branch Z1, the latter can be fed with a closely toleranced discharge voltage U_E via the converter W1, even during charging operation of the energy storage means B1.

In a first type of feed operation, when the generator is at a standstill, in the case of a peak load in the first voltage supply branch Z1 or failure of the first DC converter W1, a power flow can be fed into the first voltage supply branch Z1 from the energy storage means B1, which is otherwise disconnected during normal operation. In the simplified design of the converter W3, the second DC converter W2 is switched off and the power circuit breaker LS is closed for this purpose.

In a second type of feed operation, in order to provide further support to the supply in the first voltage supply branch Z1, a power flow is additionally fed into the first voltage supply branch Z1 from the second supply voltage branch. For this purpose, in the simplified design of the converter W3, the power circuit breaker LS is closed and the converter W2 is regulated such that a power flow from the second voltage supply branch Z2 to the first voltage supply branch Z1 is established, the output voltage of the converter W2 being regulated down to the discharge voltage U_E.

In order to provide the starting power, feedback from U3 to U2 may possibly also be provided. For this purpose, during feedback operation, the multiple converter W3 can be regulated such that, in order to provide starting power, a power flow can be fed into the second voltage supply branch Z2 from the first energy storage means B1, in order to produce in the second energy storage means B2 a state of charge capable of starting the engine.

For this purpose, in the simplified design, the second DC/DC converter W2 can be designed as a bidirectional converter (step-up/step-down controller, Buck-boost converter). Alternatively, one possibility for W2 is the parallel connection of a unidirectional converter with a bidirectional converter which, in terms of their output are matched to the power flows typically required. In reverse operation, the bidirectional converter is used to charge the battery B2 of the second voltage supply branch Z2 from the first energy storage means B1. In forward operation, the unidirectional converter connected in parallel can also be used to cover peak loads in the first voltage supply branch Z1.

Within the context of future on-board electrical system applications, it may be expedient to design the first DC converter W1 to be bidirectional as well, in

order here to provide an additional feedback current path from the first voltage supply branch Z1 to the second Z2.

In order to increase the voltage quality and the security of the supply, it is possible to resolve the first DC converter W1 into a number of converters of lower power which are distributed at different locations in the vehicle and feed into the first voltage supply branch Z1.

If, in spite of all the precautions, starting by external means should be required, this is done in the form of charging at least one of the energy storage means B1, B2 of the vehicle, until the starting and operating capability under its own power is possible, since in future vehicles some loads which are relevant to safety will be allocated to serviceable energy storage means. It will therefore be necessary to provide an appropriate feeding device for controlled feeding under current limitations. For reasons of compatibility, this is preferably carried out on the U1 side or the U3 side, for example on one of the converters W1, W2, W3, by means of a standardized plug.

The on-board electrical system structure, combined with suitable on-board electrical system management, offers an increase in the availability and operational reliability. Because of the partial redundancy of the energy storage means B1, B2, the use and the development of systems which are critical for safety are facilitated. In particular, the result is redundant safeguarding of safety-critical control electronic units, in that the latter can be fed from both voltage supply branches Z1, Z2.

However, a basic precondition is the design of the generator G for the largest permanent load occurring in the on-board electrical system. With suitable on-board electrical system management, the necessary peak output can be limited, and the energy budget can be optimized. The on-board electrical system management ensures that the voltages remain within specified limits. Precautions must be taken against overvoltage during load-shedding or starting by external means, and against pole reversal. In particular, the generator must contain a means to provide a rapid downward control action in order to avoid overvoltages in the event of load-shedding. If necessary, a central safeguard against overvoltage must be incorporated.

The two energy storage means B1, B2 can be optimized for their functions; in particular it is advantageous to design the energy storage means B2 for optimum power with respect to the supply of the starter S, for example as a super

capacitor, and to design the energy storage means B1 as an optimized-power battery. In the second voltage supply branch Z2, the average power is provided by the generator G. In the normal case, peak outputs are covered by the energy storage means B2.

Starting reliability is increased by the separated energy storage means of the two voltage levels, in conjunction with a suitable mode of operation switched by the on-board electrical system management. In order to ensure starting reliability, the objective is not to load the second energy storage means B2 (36 V battery) with quiescent current. For this purpose, when the internal combustion engine is switched off, in the normal case the DC/DC converter W1 is switched to block the path from U2 to U1, which prevents the energy storage means B2 being discharged at the cost of the starting power. Furthermore, provision may be made for loads operated at U2, which can also normally be operated when the internal combustion engine is switched off, to be capable of being switched off by the on-board electrical system management in an emergency.

In order to monitor the state of charge of the two energy storage means B1, B2 and/or the voltage in the two voltage supply branches Z1, Z2, a monitoring device is provided which is advantageously integrated into the multiple converter W3, since the latter is connected to the terminal voltage of the two energy storage means B1, B2. Depending on the detected voltage and load relationships, the monitoring device can put the multiple converter W3 into the operating modes already explained.

In order to avoid excessively frequent discharging of the first energy storage means B1 (12 V battery) in spite of the fact that the generator G is running, a power management function with a power distributor controlled by the latter can be integrated in the vehicle. It can obtain information from the multiple converter W3 relating to the state of charge and to the power balance of the first energy storage means B1. For this purpose, in addition to a communications device for communication with a power management function, a current measuring device can be integrated into the multiple converter W3, it being possible for the internal resistance of the power circuit breaker LS, which is designed as a MOSFET switch, to be used as the measuring resistance for balancing the charge.

For future battery technologies (for example lithium ion), a special charging regime avoiding overcharging and excessive discharging of the battery is

absolutely necessary. Such a device for battery charging and battery monitoring can expediently be integrated into the multiple converter W3.

Fig. 2 illustrates a preferred embodiment of the power supply circuit according to the invention, with its physical arrangement in the vehicle. Functionally corresponding components are designated by the same item symbols as in Fig. 1.

Arranged in the front part of the vehicle is the unidirectional converter W1, which could possibly be integrated directly into a generator inverter WR or a power distributor LV. The bidirectional converter W2 is expediently located close to the supply battery B1 arranged in the rear part of the vehicle.

In the two power distributors LV illustrated, the power is distributed further to loads (not illustrated in Fig. 2) in the two voltage supply branches Z1, Z2. The power distribution can in this case be controlled by a high-order power management system LM on the basis of the power budget.

The unidirectional converter W1 feeds a relatively closely toleranced 12 V on-board electrical system (first voltage supply branch Z1), to which the low-voltage or low-consumption loads NV are connected. Its output voltage U1 is regulated to a value which corresponds to the discharge voltage U_E of the battery B1. It must be dimensioned such that it covers the average power in the 12 V branch Z1.

The bidirectional converter W2 supplies the battery B1, which is isolated from the 12 V on-board electrical system Z1 during normal operation, with the optimum charging voltage U_L. If required, the connection between the 12 V on-board electrical system Z1 and the battery B1 is produced by the controlled semiconductor switch LS (e.g. MOSFET). The drive device for this switch LS, which is expediently integrated into the bidirectional converter W2, detects the voltage in the 12 V branch Z1 and, if there is an overload, produces the connection to the output from the converter W2 and the 12 V battery B1. At the same time, the output voltage of the converter W2 is reduced, and it then also supplies power into the 12 V branch Z1. If the power demand exceeds the sum of the power output from the two converters W1, W2, the 12 V battery B1 undertakes the buffering.

In order to make it possible to start a vehicle by external means with the power supply circuit according to the invention, the DC converter W2 is of bidirectional design. Therefore, instead of starting assistance, charging assistance can be provided by applying a 12 V voltage to the first voltage supply branch Z1. Trials

have shown that a battery B1 which is intact but, from the point of view of its state of charge, is incapable of starting, after it has been charged with about 400 W charging power, is capable of starting the engine in a tolerable time, even at low temperatures, for which reason the converter W2 should preferably be designed for 400 W. It is helpful that the charge fed in is initially stored in the double layer in the battery B2 and, in this way, virtually results in an increase in output from the "empty" battery, which is normally sufficient to start the engine. However, external charging assistance should in any case be necessary only in exceptional cases, since the starting battery B2 can also be brought into a state in which it is capable of starting by being fed back from the supply battery B1. In order to reduce weight by restricting the capacity of the 12 V supply battery B1 to that which is absolutely necessary, it should be ensured that this battery B1 is fundamentally kept at a state of charge of more than 80%, and is also not damaged by overcharging as a result of an excessively high charging voltage. A precondition for this is the temperature-related regulation of the voltage which is applied to the battery B1.

A significant advantage of the circuit arrangement according to the invention is that the tolerance range of the supply voltage U1 can be reduced, in order to avoid a shortened service life as a result of overvoltage, for example of incandescent lamps, or the optimal layout of the loads in the first voltage supply branch Z1. In a conventional on-board electrical system, it is necessary, for example, for a window-lift motor to be able to pick up sufficient power, even at 9 V, in order if necessary to move stiff windows; at the same time, the said motor must not be overloaded at the maximum charging voltage. Any reduction in the permitted voltage range would therefore certainly lead to a considerable saving in terms of material and costs of the connected loads. The voltage limits specified in conventional on-board electrical system specifications for the 14 V branch include the full voltage range which results from the necessary charging voltage and the discharge voltage of the battery B1 during buffering operations in order to cover power peaks or to supply loads when the engine is at a standstill. Meeting the requirement for a still more closely toleranced voltage can therefore only be achieved by means of the isolation of the battery B1 according to the invention.

For a supply battery B1 using lead-acid technology, the regulated voltage from the converter W1 could be 12.3 V, for example. During generator operation, a closely toleranced voltage range from about 11.8 V to 12.8 V could be

achieved with it. A similar voltage range can also be achieved with a three-cell lithium battery, so that the arrangement described is open to the future development of the technology. As a further advantage, the isolation of the battery B1 makes it possible to implement a charging regime which is matched optimally to the respective battery technology.

During battery operation with the internal combustion engine switched off, the 12 V on-board electrical system Z1 must be supplied by the 12 V battery B1. In order to avoid losses for the opening of the semiconductor switch LS, it is expedient to bridge across the latter by means of the normally closed contact of a relay R connected in parallel.

The bidirectional converter W2 has access to the terminal voltages of the two batteries B1, B2. One possibility would therefore be to arrange functions for monitoring the state of charge in the said converter. This information can be made available to a higher-order power management system LM via a data bus (CAN-BUS) or can be used internally for regulating an exchange of charge between the two batteries B1, B2.

Claims

1. A power supply circuit for an on-board electrical system of a motor vehicle, having two voltage supply branches at different voltage levels, the first voltage supply branch being fed from the second voltage supply branch via an electrical DC converter, and the second voltage supply branch being fed from a generator, at least one voltage supply branch being buffered by an associated energy storage means,

wherein there is a multiple converter having three voltage levels, whose one input/output is connected to the second voltage supply branch, whose other input/output is connected to the first voltage supply branch and whose third input/output is connected to an energy storage means assigned to the first voltage supply branch, the multiple converter permitting a variable division of the power flows between various inputs/outputs as required.

2. A power supply circuit according to Claim 1, wherein the DC converter continuously feeds the first voltage supply branch with a voltage, which corresponds to a discharge voltage of the first energy storage means.

3. A power supply circuit according to Claim 1, wherein during a charging operation, the multiple converter is regulated such that the first energy storage means is fed from the second voltage supply branch, the third input/output, which is connected to the first energy storage means, being regulated to a charging voltage of the first energy storage means.

4. A power supply circuit according to Claim 1, wherein in normal operation, the multiple converter is set such that it feeds no power flow into the first voltage supply branch.

5. A power supply circuit according to Claim 1, wherein, in a first type of feed operation, the multiple converter is regulated such that a power flow can be fed into the first voltage supply branch from the first energy storage means.

6. A power supply circuit according to Claim 1, wherein, in a second type of feed operation, the multiple converter is regulated such that, in order to buffer power peaks, in addition to a power flow from the first energy storage means, a power flow from the second voltage supply branch can be fed into the first voltage supply branch.

7. A power supply circuit according to Claim 1, wherein in feedback operation, the multiple converter is regulated such that, in order to provide starting power, a power flow can be fed into the second voltage supply branch from the first energy storage means, in order to produce in the second energy storage means a state of charge capable of starting the engine.

8. A power supply circuit according to Claim 1, wherein in order to monitor the state of charge of the two energy storage means and/or in order to monitor the voltage in the two voltage supply branches, a monitoring device is provided which is integrated into the multiple converter.

9. A power supply circuit according to Claim 1, wherein a current measuring device for balancing the charge for the first energy storage means is integrated into the multiple converter.

10. A power supply circuit according to Claim 9, wherein the internal resistance of the power circuit breaker, which comprises a MOSFET switch, is used as the measuring resistance for balancing the charge.

11. A power supply circuit according to Claim 9, wherein a communications device for communication with a power management device for the on-board electrical system is provided in the multiple converter.

12. A power supply circuit according to Claim 1, wherein a device for battery charging and battery monitoring for the first energy storage means is integrated into the multiple converter.

13. A power supply circuit according to Claim 1, wherein the multiple converter is formed by a DC converter and a power circuit breaker, the DC converter being adapted to regulate a power flow from the second voltage supply branch to the first energy storage means and the power circuit breaker being adapted to isolate the first voltage supply branch from the energy storage means and the DC converter .

14. A power supply circuit for an on-board electrical system of a motor vehicle, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.

The Patent Office

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14

Application No: GB 9923543.4
Claims searched: 1 to 14

Examiner: Nik Dowell
Date of search: 1 February 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H2H - HBCH, HDV

Int Cl (Ed.7): B60R - 16/02 H02J - 1/10, 7/00, 7/14, 7/34 H02H - 7/18

Other: Online : WPI, EPODOC, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	WO 84/01475 A1 (Vanner Inc)	-
A	EP 0 593 299 A2 (Ford Motor Company)	-
A	EP 0 539 982 A2 (Mitsubishi)	-
A	US 5 334 926 A (Nissan Motor Co Ltd)	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.